

Method for compressing the working fluid during a  
water/steam combination process

5 The invention relates to a method for compressing the  
working fluid in a combined cycle water/steam process  
in multi-stage turbocompressors with intercooling in  
the individual compression stages by addition of a  
coolant to the working fluid. Such a technical solution  
10 is required in the production of useful energy by means  
of combined cycle water/steam processes.

It is known that intercooling during the compression of  
the working fluid in turbocompressors reduces the  
15 compressor power required. It is known from gas turbine  
technology (J. van LIERE/C.G. MEIJER/G.H.M. LAAGLAND:  
Leistungssteigerung und Nox-Reduktion der Gasturbinen  
durch SwirlFlash®-Overspray-Eindüsung [Power increase  
and Nox reduction in gas turbines by SwirlFlash®  
20 overspray injection], VGB PowerTech 2/2002) to mobilize  
power reserves by reducing the compressor power by  
virtue of coolant addition during gas compression. For  
this purpose, finely atomized water in the form of  
mists made up of microdroplets is preferably used as  
25 coolant. When this technique is used, a two-phase  
working fluid is formed from the fuel gas or the flue  
gas and the evaporated coolant. In the first place,  
this leads to the desired reduction in temperature of  
the compressed working fluid and of the technical  
30 apparatus used. Furthermore, owing to the cooling  
processes, reductions in pollution gas concentrations  
in the flue gases are described. At the same time,  
however, it is entirely possible that the increase in  
moisture will lead to complications in the downstream  
35 process stages. The combined cycle water/steam process  
likewise aims to reduce the power requirements for  
compression by intercooling of the individual  
compression stages during the compression of the

working fluid in the form of steam in order for it to be possible to take off greater useful power from the common turbine and compressor shaft. However, the indirect cooling of the compression stages turns out to be technically very complicated on account of the high flow rates. It has as yet not been possible to find a practicable and convincing technical solution to this problem for the combined cycle water/steam process.

The object of the invention is therefore to produce a technical solution with the aid of which the shortcomings of the known prior art can be overcome. In particular, a technical solution is required which is suitable for efficient intercooling of the working fluid during multi-stage compression and thus for maximum possible reduction of the compressor power.

The object is achieved by the features of claim 1. Preferred variant embodiments are described in the subclaims. Accordingly, during the compression of the working fluid of a combined cycle water/steam process ("WDK process") in multi-stage turbocompressors, the intercooling in the individual compression stages is carried out by addition of a coolant to the working fluid. For this purpose, very finely atomized water, which is obtained by pressure-atomization of water to form microdroplets, is used as coolant. The individual water microdroplets have diameters of less than 50  $\mu\text{m}$ , preferably of between 2 and 20  $\mu\text{m}$ . In this connection, the coolant in the form of water mists is added to the working fluid directly in at least one compression stage, the coolant passing into the state of aggregation of the working fluid during the compression operation.

The coolant is preferably supplied to the working fluid in such a quantity that the thermal equilibrium is maintained. In this connection, the evaporation of the coolant takes place along the saturation curve. The

- addition of coolant quantities between the compressor inlet and the compressor outlet results directly in an increase in the working fluid mass flow. The process engineering measures mentioned give rise to a number of
- 5 desirable technical effects at the same time. By virtue of the evaporation heat required for the evaporation of the coolant being taken directly from the compression process, a reduction in the temperatures of compressed working fluid and technical apparatus is brought about.
- 10 Parallel to this, the mass flow through the compressor is increased, and a reduced compressor power is required. The steam turbine operating on the same shaft can consequently deliver an increased net power.
- 15 In a particular embodiment it is provided for the coolant to be obtained from the liquefied working fluid of the WDK process in the form of steam condensate.
- The possibility also exists of supplying the coolant to
- 20 the working fluid even before the first compression stage. The thermal energy required for the evaporation of the coolant during compression is taken from the compression system, consisting of turbocompressor and working fluid, which leads directly to a reduction in
- 25 the apparatus and medium temperatures. The mass flow of the working fluid in the turbocompressor can be made variable by virtue of the controllable addition of coolant proportions to the individual compression stages.
- 30 The compression volume is reduced owing to the internal cooling of the working fluid. For the purpose of intercooling during compression of the working fluid by means of turbocompressors, the use of cooling surfaces and the use of indirect cooling measures can, if
- 35 required, be dispensed with.

The advantages of the invention consist in essence in the technical possibility now available of not only

making the WDK process more energy-efficient but also of dispensing entirely with special measures in terms of technical apparatus for the purpose of intercooling of the working fluid between the individual compression stages in the form of cooling devices outside the turbocompressor or cooling measures on the compressor blades. Losses of working fluid occurring in the WDK process as a whole can be compensated specifically at least partly via the addition of coolant in the compression stage. In other cases, the working fluid removed from the WDK process for external purposes, for example when steam quantities are removed for heating purposes, can be replaced during the compression process by addition of coolant.

The invention is to be explained in greater detail below with reference to an illustrative embodiment.

In the accompanying drawing,

Fig. 1 shows a diagrammatic sectional illustration through a turbocompressor with an indication of the proportion of working fluid and coolant on entry into the turbocompressor, and

Fig. 2 shows a diagram to indicate the characteristic of the coolant proportion in the overall mass flow of working fluid and coolant over the individual stages of a 13-stage turbocompressor.

#### **Illustrative embodiment**

According to Figures 1 and 2, the expanded water vapour leaving the steam turbine is, in a WDK process, supplied to a turbocompressor arranged on the common shaft to be compressed again. The turbocompressor has 13 compression stages. Before the working fluid enters

the turbocompressor, coolant is added to the working fluid in a ratio of 0.15 mass parts coolant to 1 mass part working fluid. In this connection, the coolant consists of a water spray, which is obtained by atomizing steam condensate. The diameters of the individual droplets of the water spray are smaller than 25  $\mu\text{m}$ . Owing to the compression in stages of the mixture consisting of steam and water spray, a virtually continuous temperature increase, which runs parallel to the reduction of the coolant proportion in the overall mass flow, is achieved over the individual compression stages until the compressed working fluid leaves the turbocompressor. The compressed working fluid then returns to the steam turbine. The mechanical power obtained from the steam turbine is delivered to the turbine shaft. On account of the lower power of the turbocompressor, an increased excess power can be delivered to the outside on the turbine shaft. The direct addition of coolant to the working fluid dispenses with intercooling arrangements, which are complicated as far as technical apparatus and control are concerned, between the individual compression stages.